Course: ASTR 452
Term: Spring 2020
Room: Herman Brown 254
Class: TTh, 2:30-3:45

INSTRUCTOR CONTACT INFORMATION

Instructor: Matthew G Baring
Office: Herman Brown 366
Email: baring@rice.edu
Office Hours: TW 1:00-2:30pm

COURSE OBJECTIVES AND LEARNING OUTCOMES

This course is at the graduate level. As such, it is part of the core curriculum for astrophysics PhD students at Rice, along with ASTR 451 (Astrophysics I: Sun and Stars). Together they provide a year-long grounding in the branch of physics that deals with celestial objects and the distant Universe, serving as essential preparation for all budding professional astronomers and astrophysicists. For the undergraduates (usually seniors) taking this course, it serves a fast-track towards future graduate studies in astronomy, and a deeper examination of extragalactic astrophysics that they tasted in ASTR 360 as juniors.

Objectives: The goal is to provide students with a basic understanding of the larger structure of the Universe, its evolution from very early stages to the present, how constituent elements such as galaxies are formed, developed and classified, and also offer an introduction to some of the more exotic cosmic objects such as active galaxies and gamma-ray bursts. It explores how observational data can constrain this understanding, and what physics is needed to comprehend Nature at its most magnificent. Students will learn how to assemble various of pieces of physics from disparate areas of the Rice physics curriculum to bring to bear on a wide selection of astrophysical problems in the larger Universe. These will include plasma physics, nuclear physics, quantum theory, relativity, gravity and electromagnetism. Students will be taught to think logically and critically about what are reasonable assumptions in models and what are not, how to pose hypotheses and then test them. They will also be taught how to think "laterally" in the sense of connecting seemingly unrelated pieces of information with common threads of physics and astrophysical understanding. Another aim is to use and develop skills from mathematical and computational portions of the Rice undergraduate curriculum in these astrophysical contexts. In addition, the course intends to give students the opportunity to do a small amount of reading research, and communicate their findings both verbally and orally to their peers.

Learning Outcomes: By completing the course, students will be in a much better position to assess posed problems, suggest hypotheses for observed phenomena, test their ideas, develop efficient strategies for probing their speculations, and draw conclusions from their investigations. They will receive a modicum of training to communicate their ideas, hypotheses and understanding of select issues to an ensemble of their peers. This is the essence of the research process: think critically, probe, discover, revise one's perspective and tell the broader community of the results and the path taken to get there, and where to go next. This is invaluable training for an array of professions and potential careers down the line, including industry, business and academia.

REQUIRED TEXTS AND MATERIALS

Galaxy Formation, by Malcolm Longair (Springer, Berlin)

This provides the basis for much of the course, and is an essential supplement to the lectures. Notes for some course material not contained therein will be provided.

SUPPLEMENTARY SUPPORTING TEXTS

Galaxies and Cosmology, by Françoise Combes, Patrick Boissé,
Alain Mazure & Alain Blanchard (Springer, Berlin)
[Sizeable portions of the galaxy material will come from this text.]

Principles of Physical Cosmology, by P. J. E. (Jim) Peebles (Princeton)
Cosmological Physics, by John Peacock (Cambridge)

EXAMS AND PAPERS

The course assessment will consist of six to seven approximately bi-weekly problem sheets, cumulatively constituting 50% of the total grade, one ***closed-book*** **mid-term exam** during the semester that constitutes 20% of the grade, one **teaching project** in the form of in-class lecture presentations worth 10% of the grade, and an ***open-book, open notes*** **take-home final exam** at the end of the semester, constituting the remaining 20% of the assessment.

GRADE POLICIES

All parts of the assessment will be graded on a curve, determined commensurately with the overall performance of past students who have taken this course at Rice. This means that present students will not only be measured relative to their peers, but also relative to the long-term body of high-caliber Rice students who have enjoyed the experience of this course.

Late homeworks will automatically receive a **5% reduction in credit**, unless an extension has been negotiated with Prof. Baring. Homeworks that are **4-7 days or more overdue** will be **reduced by 30%** in total credit. Beyond that timeframe, late homeworks will not be graded and score zero. This policy is adopted because it is (i) not fair to other students to have the return of their homeworks in a timeframe that is substantially delayed by inadvertent tardiness by any student, and (ii) not fair to impose logistical constraints on Prof. Baring in terms of grading.

Extensions of homework deadlines must be negotiated with Prof. Baring prior to the original deadline, with the student defining good cause for the extension. The negotiated deadline will substitute for the original one in terms of the aforementioned late penalties.

The final exam must be submitted prior to the University-mandated deadline of 5pm on Wednesday, 6th May, the end of Spring Semester, 2020.

Exceptions to these late policies can occur for extenuating circumstances such as student illness, family illness or emergency. In such cases, it is the student's responsibility to let Prof. Baring know (ahead of time, if possible) what is going on so that he is not "in the dark." The student will need to (retroactively) document the circumstances.

CLASS ATTENDANCE

The purpose of the lectures is to impart knowledge distilled to its essentials on the subject matter of the course and in a manner more efficient than is afforded by merely reading textbooks and browsing Web sites; these important out-of-class learning paths are intended to supplement, not replace lectures. A central ingredient of this classroom forum is leveraging the extensive research experience and science connections of the Lecturer, and this is best done by attending lectures. The small average class size underpins an exceptional learning experience that sets Rice apart from many of its peer institutions. **Students should take advantage of this opportunity by habitually attending classes**; their learning curve will be enhanced by such dedication.

ABSENCE POLICIES

Infrequent absences are not a problem. If a student is noted to be absent for an extended period of time, or frequently, the student must communicate with Prof. Baring the reasons of the absence(s). Such cases normally will degrade the efficiency of learning for the student. Again, if there are extenuating circumstances such as student illness or family illness or emergency, accommodations will be made, and Prof. Baring should be informed. Otherwise, in the face of any absence, it is the student's responsibility to acquire the pertinent notes/materials to guide their study accordingly. Prof. Baring is under no obligation to provide copies of notes to students who do not attend a given lecture, nor to "re-lecture" such material during office hours.

IN-CLASSROOM TECHNOLOGIES

The learning environment for individuals and the entire class is optimized if it is not disrupted by cell phone activity. Use of cell phones to text or via another mode is distracting to the lecturer and shows inattention on the part of the perpetrator. Moreover it is rude to the lecturer, who invests considerable time in preparing lectures to facilitate the learning of the entire class, and to other students when a distracted moment arises. Dr. Baring **prohibits the use of cell phones in the lecture room**; if a student cannot wait until the conclusion of class to send a text or make a call, he or she should quickly excuse themselves, leave the room, and return only when finished and ready to concentrate on the lecture. Use of laptop computers to take notes is not intrusive and is acceptable to Dr. Baring; use of them to perform telecommunication functions such as Skyping and email is similarly not permitted. **Violations of these rules will lead to the student being asked to leave the classroom for the remainder of the lecture.**

RICE HONOR CODE

In this course, all students will be held to the standards of the Rice Honor Code, a code that you pledged to honor when you matriculated at this institution. If you are unfamiliar with the details of this code and how it is administered, you should consult the Honor System Handbook at http://honor.rice.edu/honor-system-handbook/. This handbook outlines the University's expectations for the integrity of your academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process.

The mid-term and final (take-home) exam questions are not to be discussed at all with other students, faculty or graders, and are subject to the provisions of the Rice Honor Code. Please verify this by **writing the word pledge and your signature on each exam**. Questions specifically about exams should be directed only to Prof. Baring.

DISABILITY SUPPORT SERVICES

If you have a documented disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with Disability Support Services (Allen Center, Room 111 / adarice@rice.edu / x5841) to determine the accommodations you need; and 2) talk with Prof. Baring to discuss your accommodation needs *during the first two weeks of class*.

Any letter from DSS to the instructor requesting accommodations for the student should be delivered in the first three weeks of semester, so that Prof. Baring can plan accordingly.

SYLLABUS

The detailed syllabus below gives the layout of the course material. For further information, such as scheduling, pointers to related chapters in the Required Text, etc., see the ASTR 452 course web pages at http://www.ruf.rice.edu/~baring/astr452/astr452.html/ .

Cosmological Entreé

Mach's Principle
The Cosmological Principle
Homogeneity: Flux Distributions
Large Scale Structure

Cosmic Distances and Cosmochronology

Hubble's Law
Tully-Fisher Distances
Supernova Surveys
Cosmochronology: Potpourri
  Gravitational Instability
  Globular Cluster Constraints
  White Dwarf Cooling
Cosmochronology: Nucleosynthesis
  Radio-Isotope Dating

Newtonian Cosmology

The Fluid Newtonian Universe
Newtonian Expansion/Collapse

Elements of General Relativity

Foundations of General Relativity
  Equivalence Principle
  Gravitational Time Dilation and Light Bending
  Precession of the Perihelion of Mercury
Einstein's Field Equations for Gravity
  Metrics and Equations of Motion
  Force and Action: the Field Equations
  The Schwarzschild Metric

Relativistic Cosmology

Robertson-Walker Metric
Friedmann Equation
  Critical Density
Matter-Dominated Universes
  Deceleration Parameter
Radiation-Significant Cosmologies
The Cosmological Constant

Observational Cosmology

- Connecting to the Real World
  - Lookback Times
  - Flatness Problem
  - Angular Diameter Distance
  - Luminosity Distance

The Thermal Universe

- Cosmic Microwave Background
  - Anticipation
  - Discovery
- COBE and WMAP Results and Implications
  - Acoustic Oscillations: the Robust Cosmic Ruler
  - Baryonic Seed Timescale
  - WMAP: the Era of Precision Cosmology
- Recombination Era
- Redshift of Last Scattering

Big Bang Nucleosynthesis

- Primordial Nucleosynthesis by the pp Chain
  - Neutrino Decoupling
  - Neutron Freeze-out
  - Deuterium Synthesis
  - Helium and Lithium Production

Big Bang Inhomogeneities and Inflation

- Dynamics of Linear Density Perturbations
  - Non-Relativistic Matter Case
  - Structure Growth in Radiation-Dominated Epoch
- Jeans Instability
  - Radiation-Dominated Epoch
  - The Ensemble Picture

The Milky Way

- The Morphology of the Galaxy
- Galactic Rotation Curve
  - Kinematics of the Milky Way
  - Evidence for Dark Matter
  - Dark Matter
- The Galactic Center

Normal Galaxies I: Spirals

- Hubble's Classification of Galaxies
- Spiral Galaxies
  - Radial Structure in Disk Geometry
  - Vertical Structure of the Disk
  - Disk Warping
- Spiral Structure

Normal Galaxies II: Ellipticals

- Elliptical Galaxies
  - Populations of Ellipticals
  - King's Model: Spherical Galaxies
- Galactic Evolution
  - Gravitational Relaxation
  - The Role of Gas Cooling

Active Galaxies I: Seyferts and Quasars

- Global Energetics of Active Galaxies
- Seyferts
  - Eddington Luminosity Limit
  - Hydrodynamic Spherical Accretion
- Quasars

Active Galaxies II: Radio Galaxies and Blazars

- Radio Galaxies
  - Superluminal Motion and Doppler Boosting
  - Shock Acceleration
  - Hot Spots in Radio Lobes
- Blazars and AGN Unification

Galaxy Clusters and Dark Matter

- Galaxy Clusters
- Cluster Structure and Content
  - Hot Gas and Bremsstrahlung
- Sunyaev-Zeldovich Effect
- Gravitational Lensing
- Forms of Dark Matter

SYLLABUS CHANGE POLICY

This syllabus is only a guide for the course and is subject to change without advanced notice.